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Briquette making in Kenya: Nairobi and peri-urban areas

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ABSTRACT

Briquettes made from biomass residues could contribute to ensuring the sustainable supply of biomass energy. The paper reviews the present briquette making process in Kenya especially in Nairobi and peri-urban areas. The paper introduces the energy situation in Kenya, then the briquette making process and finally presents the challenges and opportunities in briquette making. In the opportunities section, eighteen briquette producers participated in the question and answer exercise to quantitatively provide information on briquette making. Most producers use bare hands (handmade briquettes), others make use of novel-based machines such as ram-piston type, motorized screw press, shredder, wooden press and the mold-box piston type all made from locally available materials. The mixing ratios and the various ingredients used in briquette making are haphazard with no standard ratio and specific mixture for optimum briquette production. Despite these, most briquette producers are well along in the briquette business. At the same time, the end-use consumers are very positive in using the briquette fuel as an alternative fuel. Some of the end-use consumers are the schools, churches, hotels and some households. This study indicates that the opportunities for briquette making are immense and could help curb deforestation thereby reduce environmental degradation.

Contents

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1. Introduction

1.1. Geography and other information in Kenya

Kenya lies across the equator located on the coast of the Indian Ocean covering an area of about 582,650 km^2 [1]. According to the recent census [2], there are 39.5 million people in Kenya.

The country has a tropical climate with different topographical regions experiencing different climates: the coastal region is hot and humid; the northern part is dry while the inland is temperate. Sunshine is experienced throughout the year with alternating cool conditions at night and early morning. Nairobi, the capital city of Kenya, has an altitude of 1661 m with temperatures ranging from 13.60 °C to 25.20 °C. Normally, the months of February to March are the hottest while July to August are the coldest [3].

1.2. Energy in Kenya

Wood fuel accounts for the largest proportion as a primary fuel in Kenya. In aggregate, wood fuel accounts for 70%, petroleum (21%) and electricity (9%) [4]. These fuels are mainly used to generate electricity, power household appliances, cooking, lighting and greenhouses [2].

Wood fuel demand is increasing with the rise in population. This situation is worsening as more people move into urban areas and more industries are established. All these need more energy. According to the Ministry of Energy (Kenya) [5], the demand for wood fuel is projected to rise to about 54 million tonnes per year by the year 2020. Table 1 shows the projected wood fuel demand up to the year 2020. The average growth in wood fuel demands is about 4.7 million tonnes per year (a linear increase of 2.7%) while the sustainable supply increases by only about 0.6% per year. The average annual increment method is used to determine the sustainable supply (tonnes per year). Fig. 1 illustrates that wood fuel demand would be higher than total average increment by about 34 million tonnes per year (deficit tonnes per year) by the year 2020.

Wood fuel is unsustainable as shown by the deficit tonnes per year together with the information that Kenya's forest cover is about 6% of total land cover [6]. Both wood fuel and wood charcoal usage are increasing on a large scale [7]. According to a survey [8], 1.6 million tonnes per year of charcoal are produced in Kenya. This value is increasing at an alarming rate and effective regulation of the charcoal industry by the government remains a key challenge. Charcoal produced is harvested from the following lands: government land (13%), individual and family land (44%), business or land owned by corporate bodies (38%) and communal land (5%) [8].

Moreover, the government of Kenya estimates that 700 tonnes of charcoal per day (about 16% of the total amount of charcoal made in Kenya) are consumed in Nairobi. 10% of the 700 tonnes per day forms charcoal dust which either clogs waterways or is dumped at the dumpsites. In Uthiru (Nairobi), a charcoal business is not uncommon, as shown in Fig. 2, indicating that most of the forest cover is cleared and destroyed for charcoal production [9].

The above findings concur with studies [10,11] that the demand for biomass energy is directly proportional to the increasing population in most sub-Saharan African countries. This has however necessitated search for alternative energy sources to overcome the anticipated deficit and ensure sustainable energy supply and security.

This paper considers the use of biomass wastes/residues to make briquettes. Historically, particularly in the industrialized world, briquette production was mainly for economic benefit such as converting the unused biomass wastes into marketable fuel that could be transported over long distances. Consequently, developing countries such as Zimbabwe, Mozambique and Romania [12–14] respectively, have carried out evaluations to ascertain potential of biomass wastes/residues. These evaluations are a follow-up to the finding that the global potential of sustainably harvested agricultural and forest residues could be converted into nearly 50 EJ of energy per year

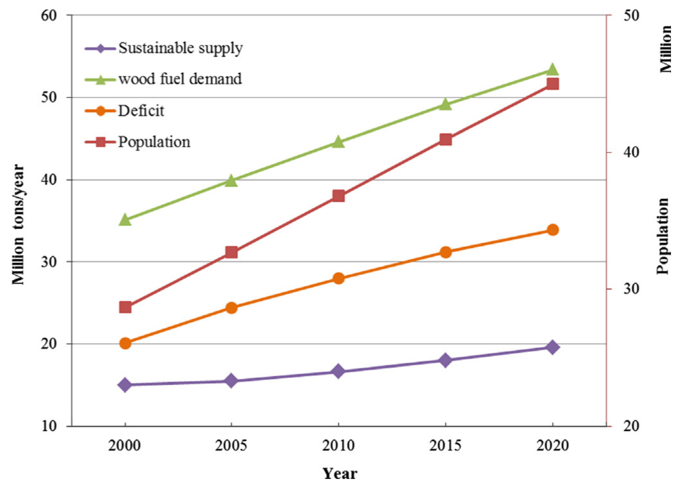


Fig. 1. Graphical representation of wood fuel demand and supply as depicted in Table 1.

Fig. 2. A charcoal open-air market in Uthiru, Nairobi. Every drum famously known as 'debe' sells @ 0.625$. American dollars, where 1$=80 Kenya shillings.

Table 1
Wood fuel demand and supply by the year 2020 in Kenya.
Source: [5].

Years	Yr.2000	Yr.2005	Yr.2010	Yr.2015	Yr.2020
Population	28,686,607	32,694,444	36,810,671	40,941,673	44,981,767
Demand (tonnes/yr)	35,119,615	39,896,632	44,599,347	49,164,960	53,416,327
Sustainable supply (tonnes/yr)	15,024,510	15,488,936	16,634,550	17,984,406	19,559,738
Deficit (tonnes/yr)	(20,095,105)	(24,407,696)	(27,964,797)	(31,180,555)	(33,856,589)
Deficit (%)	−57.2	−61.2	−62.7	−63.4	−63.4
Deficit (tonnes/person)	−0.701	−0.747	−0.760	−0.762	−0.753

(EJ y^{-1}) [14–16]. This corresponds to about 12% of the total global energy consumption [16].

Similarly, a feasibility study carried out describes the availability of biomass wastes/residues in Kenya [17]. The amount of biomass wastes available are about 4.5 million tonnes per year. The feasibility study complements previous studies indicating that large volumes of biomass residues are generated annually in developing countries [18–20].

Despite previous studies on the availability of biomass wastes, not much has been done to evaluate how best to utilize biomass wastes on an economic scale. So far, most studies have focused on improving stoves rather than the fuels in addition to the ways of meeting household requirements. Based on the findings from eighteen briquette producers in Nairobi urban and peri-urban areas who participated in the question and answer exercise, briquette making provides a platform to realize the environmental and sustainable attributes required of modern energy.

Biomass wastes include char fines (known as char dust), sawdust, rusk husks/straws, coffee husks/shells and maize stover, just to mention but a few. Such biomass wastes can be briquetted to provide an alternative fuel that is sustainable. Sustainable in the context of ready availability of biomass wastes for briquette production that could help curb the unsustainable forest degradation and deforestation. Although it is still a matter of debate [21,22] as to whether char dust should be regarded as unsustainable or renewable, the evidence presented here and other literature sources points to the fact that the current char dust production relies on the already unsustainable charcoal industry [23] and therefore a diversification of briquette feedstock is needed.

Generally, biomass is an almost CO_2-neutral energy source, as the absorbed amount of CO_2 during plant photosynthesis is equal to the amount when these plants are later used for energy production [24]. For briquettes, a thorough life cycle analysis needs to be done to ascertain briquette contribution to greenhouse gas emissions. The presence of binders in the briquette making might slightly alter the emission characteristics of biomass wastes. However, briquette emissions characteristics might be better than those from firewood and other biomass lower down the energy ladder. In addition, the relative cost of disposing the biomass wastes to the environment might contribute to more greenhouse gas emissions than the making of briquettes. All these suffices the whole effort of reducing greenhouse gases to keep global warming below a 2 °C increase by adoption of alternative fuels [25–27].

2. Briquettes

2.1. Introduction

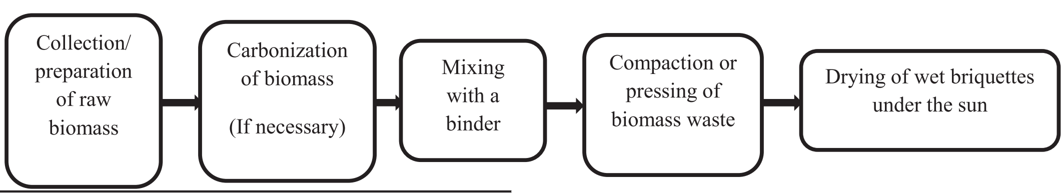
Biomass is the vital source of energy for more than 75% of the population in sub-Saharan Africa[28]. The processing and utilization of biomass is mainly characterized by traditional methods such as carbonization in traditional earth kilns and use in stoves which have efficiencies of between 10% and 20% [23]. This compounds the unsustainable harvesting of wood fuel and charcoal production from forest resources [23]. However, an improved carbonization process and use of improved cooking stoves could be synergetic in promoting briquette production, environmental integrity and sustainability efforts through the use of appropriate technology [23].

In early 1970s and 1980s, the energy crisis caused widespread awareness on the importance of renewable energy, in particular biomass, as an alternative to fossil-based fuels in developed and developing countries. Biomass, a renewable energy, drew great interest that led to new technologies to harness the easily available and abundant resources. Moreover, biomass availability in a particular region made easier utilization using novel – based machines to promote economic and environmental sustainability of a region or nation [29]. This transformation of biomass wastes into briquette fuel could enhance sustainable development while raising the living standards for the poor in developing countries [23,30].

2.2. How briquettes are made

Briquetting is carried out to improve the density, burn time and the calorific value of raw biomass. Briquetting also improves the handling and transportability of biomass. According to a study by Reed and Bryant [31], the uncompressed biomass has the calorific value of only 1/3 of charcoal by weight and 1/4 by volume, but the calorific value became 2/3 of charcoal by weight and 3/4 by volume when compressed.

Generally, briquette making in Nairobi and peri-urban areas involves the following main processing steps:



2.2.1. Current briquette feedstock preparation process

As mentioned earlier, most briquette producers use the char dust as the main briquetting material (Table 2) normally collected from the charcoal vendors as waste. The char dust in this form is already carbonized as derived from the charcoal produced by the traditional (rural) earth kiln method which is inefficient and has very low recovery rates of about 10% [23]. Furthermore, the earth kiln method (Fig. 3) is unsuitable in an urban set up such as Nairobi. For one, the method is not appropriate to carbonize other biomass wastes such as rice husks, coffee shells, maize stovers, just to mention but a few. Secondly, Nairobi being a central city has got a huge population [32] such that the space required to set up an earth kiln is limited coupled with high rents and business rates [33,34].

Waste paper is the other raw material commonly used in briquette making (Table 2). The briquette producers claimed that waste paper is easily available and mostly used as a binder. Firstly, the waste papers are sorted out to obtain non-colored papers (claimed that the colored papers are not good). Some briquette producers have fabricated a novel-based machine known as the shredder (Fig. 3) that shreds the waste papers into the required small sizes. After shredding, the shreds of paper are soaked in water (some claimed soapy water) for a period of about 24 h. This is to soften the paper fibers for easy pulping and mixing process. The process is carried out in basins or open containers and the traditional ‘kinuu[1]’ (Fig. 3).

[1] ‘Kinuu’ is a Kamba (ethnic community in Kenya) word used to refer to the wooden pulping tool.

Table 2
Briquette producers from the identification process.

S/ no.	Briquette shape	Raw materials	Mixing ratio	Briquetting equipment	Dimension of briquette	Rate of production/year/day/ month	Selling price	Number of people to operate
1	Cylindrical with central hole	Char dust, waste paper (shredded)	3:1 respectively	Piston press; at times hydraulic incorporated	D[a]: 10 H[b]: 4-5	9 tonnes from available receipts of briquettes	1 kg@0.25$ where, 1 kg ≡ 3–4 briquettes	2 (makes use of casual employees)
2	Ball-shaped	Char dust, waste paper	No particular ratio	Hand-made	H**[c]	No documentation	4 briquettes are sold @0.125$	2 (on shift)
3	Rod-shaped	Sawdust, waste papers, coffee husks	2:1 respectively	Ram/piston press, pulping machine	D:9 H*[d]: 10–15	• 216 tonnes • sold to the nearby Babadogo primary and the catholic church	Each briquette sells@0.025$	2 (on shift)
4	Ball-shaped	Char dust, dry cow dung	2:1 respectively	Hand-made	H**	• No documentation • The briquette has ready market from the nearby households	Each briquette sells@0.025$	5 (every person is assigned a specific task during production)
5	Rod-shaped	Char dust, shredded papers	2:1 respectively	Ram type-piston press	D:9 H*: 10–15	Machine has a production capacity of 1500 briquettes per day	Each briquette sells@0.0625$	2 (makes use of casual employees)
6	Rod-shaped	Char dust, clay (mainly red soil)	97% char dust and then add 3% clay(acts as the binder)	The manual and the motorized briquetting machine	D:5 H*: 8–13	• Manual briquetting machine (production capacity of 12 kg/ hr). • Motorized (production capacity of 100 kg/h). • Produces 30–50 kg bags of briquettes/week	Every 50 kg bag of briquettes sells @7.5$	2 (makes use of casual employees)
7	Cylindrical with central hole	Char dust, waste paper	Major proportion being the char dust	Wooden press	D:13–14 H:4-5	4–5 bags/day[e]	Every 25 kg bag sells @ 10$	Individually
8	Holey and cylindrical	Char dust, sawdust, waste paper	Major proportion being the char dust	Wooden press, screw press	D:6 H*: 8–10	24 tonnes/month	Each briquette sells @0.0375$	2 casual employees
9	Ball-shaped	Char dust, red soil	No particular ratio	Handmade	H**	270 kg/day	Basin sells @1.875$	Work as a group
10	Ball-shaped	Char dust, red soil	No particular ratio	Handmade	H**	270 kg/day	Basin sells @1.8875$	Work as a group
11	Ball-shaped	Char dust, red soil	No particular ratio	Handmade	H**	270 kg/day	Basin sells @1.9$	Work as a group
12	Ball-shaped	Char dust, red soil	No particular ratio	Handmade	H**	270 kg/day	Basin sells @1.9125$	Work as a group
13	Ball-shaped	Char dust, red soil	No particular ratio	Handmade	H**	270 kg/day	Basin sells @1.925$	Work as a group
14	Cylindrical with central hole	Char dust, waste papa (shredded)	3:1 respectively	Wooden press	D:13–14 H:4–5	400 pieces of briquettes	4 briquettes sells @0.1875	Assisted by two casual employees
15	Square-shaped	Char dust, waste paper	2:1 Respectively	Piston press; at times hydraulic incorporated	8 × 8	–	50 kg bag sells @8.75$	Assisted by one casual
16	Rod-shaped	Sawdust, char dust, waste paper, wood shavings	No particular ratio	Ram type-piston press	D:9 H*: 8–13	–	Still on trial stage	Work as a group
17	Cylindrical with central hole	Coffee husk, rice husk, sawdust	Purely the agricultural waste	Motorized screw press	D:5 H*	360 tonnes/year/machine	Depends on production cost	Every machine requires 5 people per 10 hours shift
18	Cylindrical with central hole	Waste paper, clay, sawdust	Sawdust to clay is 4:1 respectively	Screw press	D:8 H:4	4 briquette per minute	Depends on production cost. Although at present sells @ $0.0625	Every machine is able to employ 6 people

[a] D – diameter in centimeters.
[b] H – height in centimeters.
[c] H** – briquettes are haphazardly made using the palm of the hands.
[d] H* – height depends on extruding pressure.
[e] The production capacity is achieved in case 3 people are in operation.

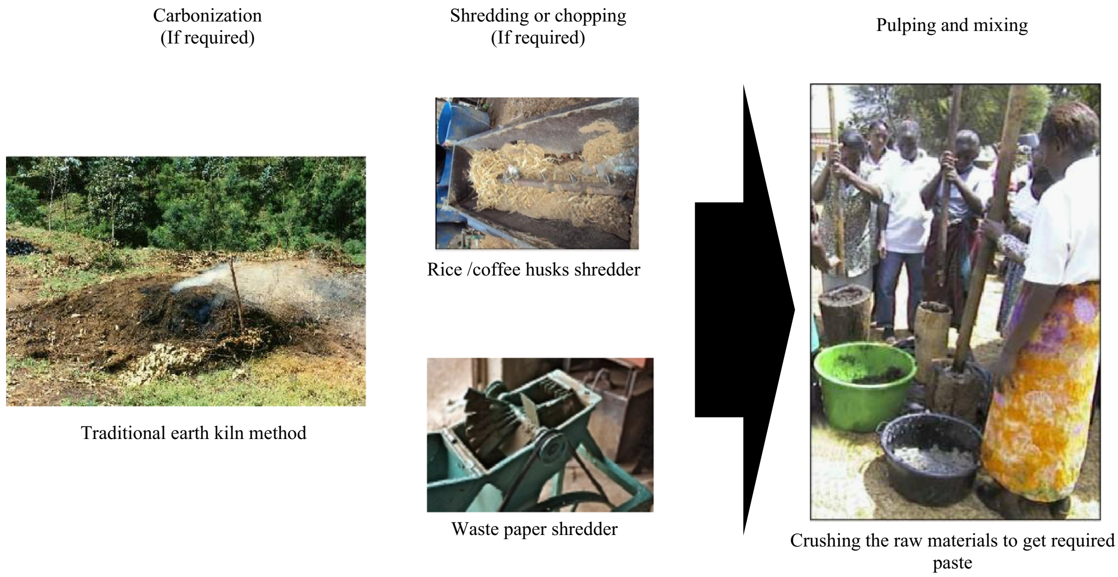


Fig. 3. Current briquette feedstock preparation process.

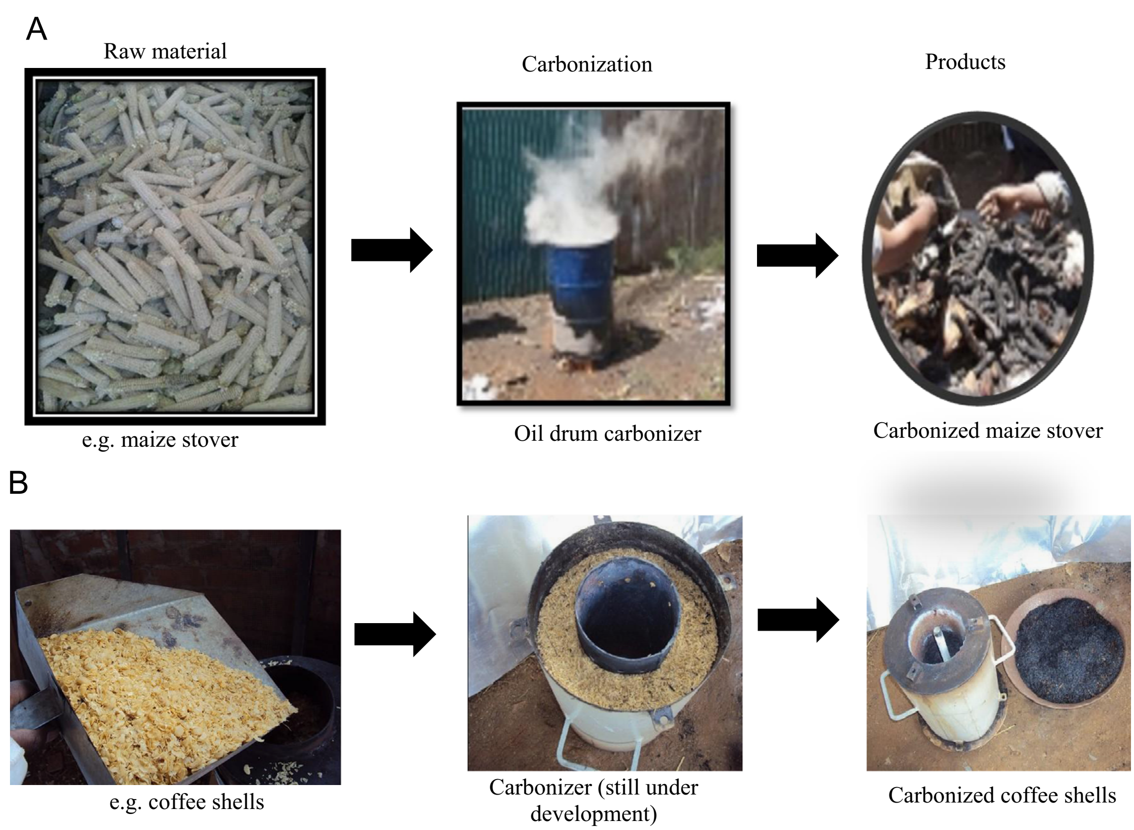


Fig. 4. Proposed biomass feedstock preparation process. (A) Demonstration carried out in Uthiru, Nairobi. (B) Demonstration carried out in an institution in Nairobi.

In Dandora (Nairobi), a rice/coffee husk shredder has been fabricated. Unfortunately, at the time of review the machine was not in good working condition (Fig. 3). The coffee husks used are normally collected from the nearby coffee industries in Industrial Area, Nairobi.

2.2.2. *Proposed briquette feedstock preparation process*

To address some of the challenges and ensure the diversification of biomass feedstock in Nairobi and peri-urban areas, the following was proposed through demonstration. Maize stover (in wet form), were collected from Gikomba market in Nairobi for briquette making. Firstly, the maize stovers were dried in open sunshine in one of the briquette producer's yard in Uthiru, Nairobi (Fig. 4A). The drying of maize stover was based on findings [35] that 10% moisture content in biomass feedstock was effective for carbonization process. The carbonization process was carried out in a used-oil drum that had been modified according to literature [36]. The advantage of using the drum is that they are readily available at a cheaper price in Kariokor market, Nairobi (about 10$ for a drum) and they are more flexible to use for they require limited space to set up. The recovery rates of the carbonized maize stovers (Fig. 4A) were about 30% which

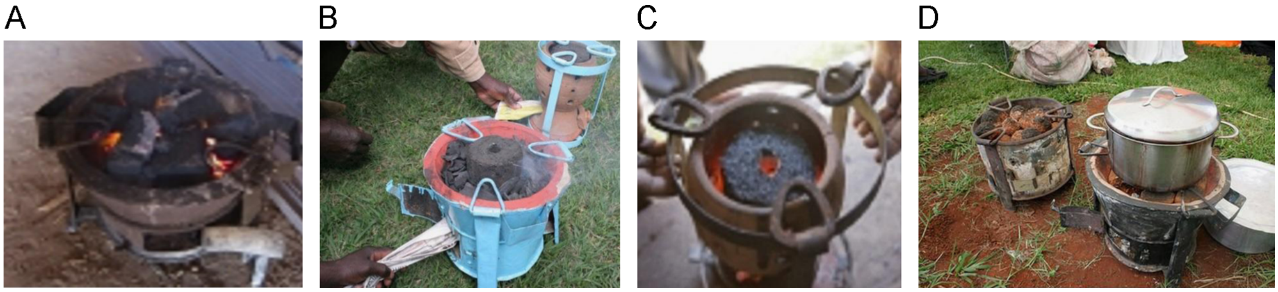


Fig. 5. Demonstration of the burning of briquettes made from different feedstock.

are within the literature values of improved carbonization systems [22]. However, the system requires further improvement to increase the recovery rates.

Similarly, another demonstration on carbonization was carried out in one institution in Nairobi with coffee husks (Fig. 4B) as the feedstock. Although the carbonizer is still under development, the obtained carbonized coffee shells (Fig. 4B) indicated improved recovery rates. No major wastage of the carbonized coffee shells was seen. However, a little percentage of ash pointed to complete combustion of part of the coffee shells within the carbonizer. More research is needed to ascertain the probable efficiency of the system.

From literature [37], carbonization improves the calorific value of biomass waste or residues. The calorific value almost doubles such that carbonized biomass has a calorific value of 25–30 MJ/kg compared to around 15 MJ/kg for non-carbonized biomass [37].

2.2.3. *Mixing with a binder*

Some biomass feedstock with moisture content (6–14%) naturally bind from subjection of pressure (4–60 Mpa) and temperatures (160–280 °C) [38]. This is due to the presence of lignin substance. According to literature material [39], lignin is the encrusting substance binding the wood cells together and giving rigidity to the cell wall. However, the temperatures cause the thermal softening of lignin material, leading to the subsequent flow to form an “entanglement network of molten polymers” [40]. Strong bonds results from the interpenetration of lignin polymer chains forming a briquette.

However, in instances where high temperatures are not achievable, additional binders are needed. The binders include fine clay, cassava flour, wheat flour, molasses, soaked waste papers and red soil. Fig. 5 shows the demonstrations carried out to illustrate the combustibility of briquettes made using the different binders. The demonstrations were carried out in both new improved cooking stoves and the old traditional stove. According to literature [41], the new improved stove has ceramic clay as the insulating material with an efficiency of about 50% while the traditional one has 15% (with no insulation). Moreover, the improved stoves offers fuel flexibility as they allow the switch over from charcoal use to briquette use at a minimal cost [27,41]. The demonstrations are as follows:

- Burning of briquettes made from a mixture of the crushed carbonized maize stover with cassava solution[2] as the binder at no specific mixing ratio (Fig. 5A). The briquettes burn producing no or little smoke and also, for a long time.
- Burning of briquettes made from a mixture of 97% of char dust with 3% of red soil (Fig. 5B). The briquettes emit some smoke on burning but burns for a long time.
- Burning of briquettes made from a mixture of three parts of char dust for every part of shredded waste paper (Fig. 5C). Exhibits slightly similar characteristics as Fig. 5B.
- Briquette made by hands from a mixture of char dust and clay at no specific mixing ratio (Fig. 5D). These briquettes emit the most smoke. Also seen in Fig. 5D is the traditional cooking stove whose efficiency, as earlier mentioned, is very low.

However, a detailed view of the various briquette producers and their production processes are found in Table 2. Much more research needs to be done to ascertain the right mixing ratios, biomass feedstock characteristics, calorific value, proximate and ultimate analysis of the briquettes, burn time and combustibility of the briquettes.

In addition, the following general observations were made:

- The challenge of igniting the briquettes such that some briquette end users use waste newspapers to ignite while some opt for the use of wax sticks [42].
- The briquettes require greater ventilation during combustion as evidenced by placing the circular-shaped briquette on top of some charcoal particles. The charcoal particles also help in speeding up the ignition of the briquette.
- The central hole in the circular-shaped briquettes, apart from offering the much needed ventilation in combustion, acts a major combustion zone in the briquette [42]. The hole creates a chimney effect that ensures more rapid ignition and efficient burning of the briquette [43].

2.2.4. *Compaction or pressing*

This process is carried out either manually (using bare hands) or mechanically (using machines). The principle behind compaction is to expel the air therefrom, especially the air that is contained in the particles of materials when received in the mold for compression. In briquetting operation, the entrapped air must be dispelled to avoid making a spongy or loose briquette. A spongy briquette deteriorates in storage and also does not exhibit desired results from the stand point of the briquette being a long burning and efficient fuel [44]. For example, the Swedish have developed standards for their briquettes [45]. The standard stipulates the density, material used and the shape of the briquette. In Nairobi (Kenya), the parameters required to stipulate briquette standard are unavailable and difficult to generate. Table 2 shows the isolated and non-synchronized nature that characterizes briquette making process. Therefore, research needs to be done to develop the Kenyan standard based on the available local materials and appropriate technology.

Some compaction machines or techniques of briquette making (Fig. 6) were found to be in use. These include both the manual and mechanical processes. Detailed description of use of various

[2] The solution formed by boiling crushed cassava root mixed with water.

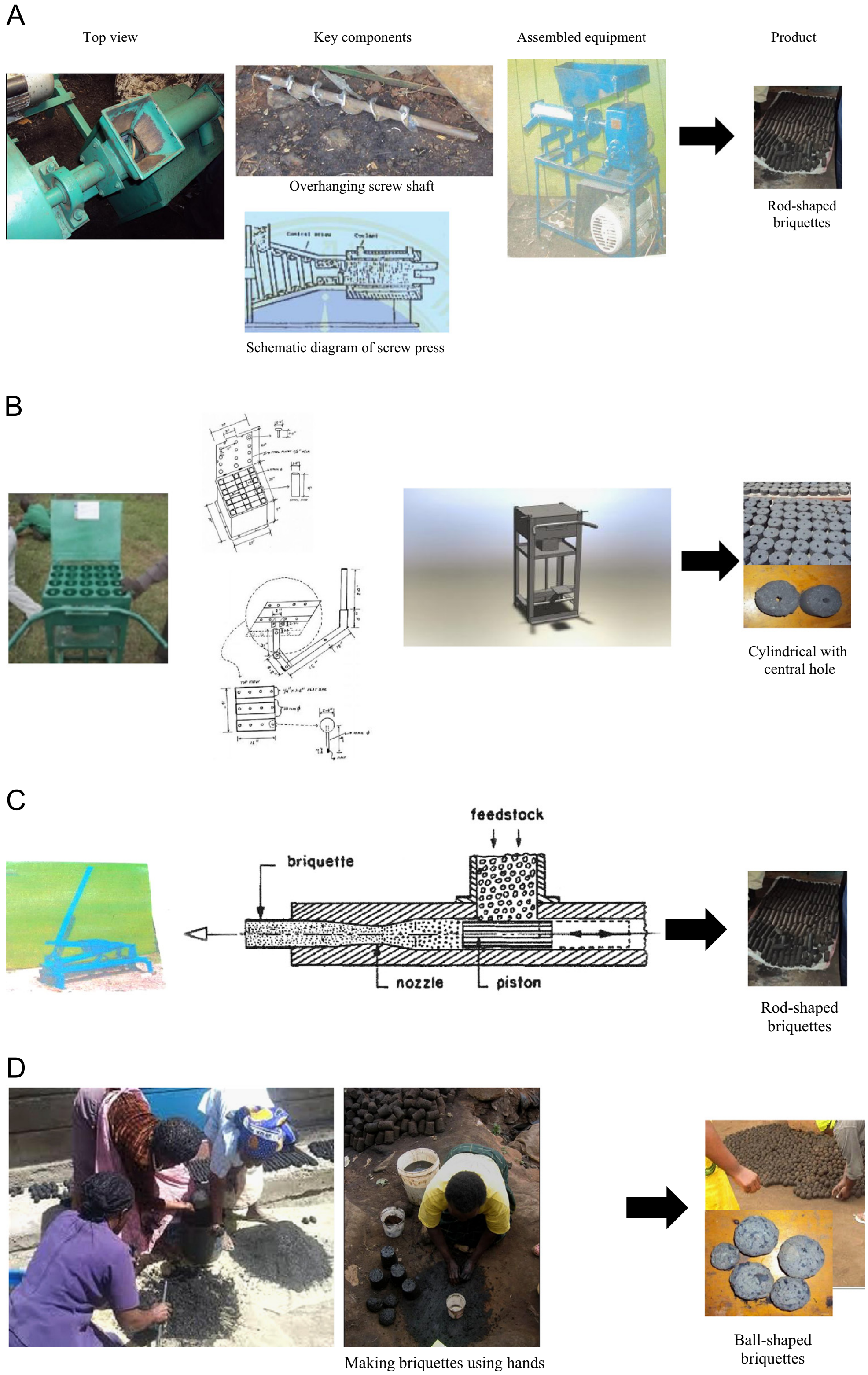


Fig. 6. Various briquette-making processes. (A) Motorized screw press machine. (B) Mold box briquetting machine. (C) Ram/piston type machine. (D) Handmade briquettes.

machines or techniques amongst the briquette producers in Nairobi and peri-urban areas (Table 2).

- The motorized screw press machine (Fig. 6A) consists of an overhanging screw shaft, a drum covering and an extruder die pipe (normally cylindrical but may be modified to any shape e.g. hexagonal). The screw shaft is mounted at the end by ball bearings while the fixed plate holds the other end. The assembled machine however, is mounted on a stand (Fig. 6A). The assembly was based on literature [45,46] and is schematically shown (Fig. 6A*). The Rod-shaped briquettes produced are shown (Fig. 6A).
- The mold-box press machine (Fig. 6B) consists of the mold box with a cover unto which a lever is rolled. The lever is piston-operated in a vertical position. The principle of operation shown under 'key components' (Fig. 6B) was based on

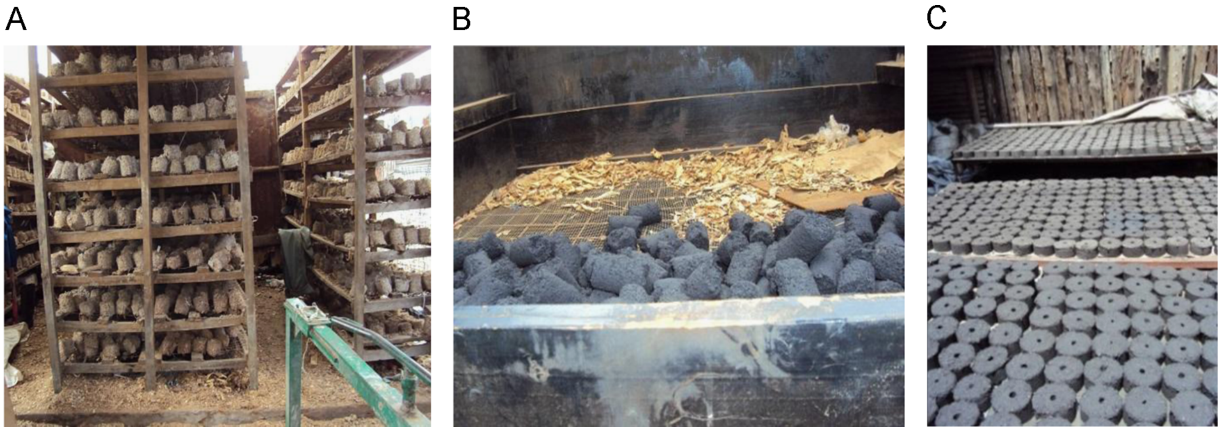


Fig. 7. Various briquette-drying methods.

literature materials [45–47]. The mold-box 10 cm (diameter) and 5 cm (high), has twenty (20) molds. The cover plate is slid open and mold filled with the feedstock to be pressed. The cover is then closed and the lever pulled down for compression. Still in the vertical position, the cover is slid aside and lever is pressed downwards to eject the compressed briquette. However, prior to ejection, the remaining water from the waste material is taken out during compression through the holes provided to that effect at the bottom of the mold. Fig. 6B* shows the assembled press machine [48]. The briquettes made are cylindrical in shape with a central hole as shown (Fig. 6B).

- The principle of operation of the ram or piston press (Fig. 6C) is based on literature material [18,45] and is schematically shown (Fig. 6C*). The produced briquettes are rod-shaped as shown (Fig. 6C).
- The manual method of making briquettes (Fig. 6D) shows how the feedstock to be briquetted is pressed in the palm of hand or in small containers. Normally, the final briquette is shapeless but often takes the shape formed by the hood of the palm, in most cases, ball-shaped.

2.2.5. *Drying of the briquettes*

Drying of briquettes is essential since the briquettes are produced in wet form. Due to the abundance of sunshine throughout the year in Nairobi and its environs, sun-drying is commonly used. Sun-drying can take up to 3–4 days to dry the briquettes. However, the sun-driers are very suitable during the rainy season to ensure the same drying period. Fig. 7 shows some of the current drying practices in Nairobi and peri-urban areas.

- The drying rack (Fig. 7A) was made and currently in use in Dandora, Nairobi. The drying rack does not have a specific size gauge as it was haphazardly constructed from readily available thrown away wooden materials dumped at the Dandora dump site, Nairobi.
- The sun-dryer (Fig. 7B) was constructed by one institution based in Nairobi. The construction was based on literature material [49] with slight modifications to optimize the parameters for drying.
- The open rack drying method (Fig. 7C) was in use in a yard in Uthiru, Nairobi.

3. Challenges

Challenges characterize the growing demand and supply for the use of briquettes. The challenges cut across all the stakeholders in the briquette industry. These include:

3.1. *Technological challenges*

The commercial viability of briquettes hinges on the quality of briquettes. High quality briquettes could be made using appropriate technology which is locally available but remains to be inaccessible to most briquette producers.

As previously shown (Figs. 3–7), the major challenge for majority of producers is lack of appropriate briquetting equipment. A close collaboration of engineers, researchers and the briquette producers is required for timely fabrication and thereon adoption of the briquetting equipment.

In addition, there is heavy reliance on charcoal fines which is already in carbonized form. This promotes non-utilization of other agricultural waste for briquette making. This is however worsened by the lack of appropriate technical know-how of carrying out the carbonization process.

Some binders such as fine clay, red soil, waste paper are associated with the production of smoky briquettes as opposed to those made from cassava solution, wheat flour and molasses. However, the challenge of using the latter is that they could create competition with food for human consumption. This requires further research on alternative binders especially for the rural households where the electrical screw press machine would be inaccessible.

Finally, some briquette producers are still using the inefficient traditional charcoal stoves (Fig. 5) for briquette combustion. The use of improved cooking stoves would be synergetic in promoting briquette usage.

3.2. *Bureaucratic challenges*

Kenya lacks the local standards for the locally produced briquettes. This is a huge challenge to some of the briquette producers who would want to export briquettes to other countries or sell to main supply stores. One briquette producer indicated that they are using the South African standard to export some of the briquettes outside the country. The finding was similar to one carried out in Uganda that they are using the South African standard just as is the case in Kenya [35]. For example, the Kenya Bureau of Standards (KEBS)[3] requires certification of any product (briquettes included) to retail in the local or national stores. The costs for certification are borne by the producer. In addition, it is a rule of thumb that new products are supposed to be sold on a consignment basis on credit to the stores [50,51]. This is a financial

[3] Government parastatal (Kenya) tasked with providing Standardization and Conformity Assessment services.

and bureaucratic challenge to a small scale briquette producer as the majority of producers engage in other enterprises such as farming, welding, hawking and many others, to supplement revenues from briquette making.

Furthermore, there is lack of a common voice among the briquette producers to push through a common agenda for the growth of the briquette industry. This is compounded by the lack of an association for briquette producers. At the time of review, the briquette producers indicated that there once existed the Kayole Environmental Management Association (KEMA). Currently, KEMA mainly focusses on domestic and urban waste management [18,52]. The briquette making focus of KEMA and other previous stakeholders has reduced substantially [53]. The association, if formed, could: ventilate and solve some of the challenges experienced by the briquette stakeholders through information sharing and technology transfer; voice concerns through the Ministry of Energy (Kenya) for the formulation of policy framework for the promotion of briquette in the country.

3.3. Access to finance

Lenders are discouraged by lack of collateral, small loan requests and the immature briquette technologies. In addition, the illiteracy levels among the briquette producers are high such that they are put off by the seemingly complicated processes of borrowing.

Lenders need to provide training or motivation such as motivation on regular saving, the procedures for borrowing loans, establishing efficient business structures and offering low interest rates on loans borrowed. This would help demystify: lenders preference for conservative and proven ideas or work with borrowers who can provide matching collateral, or both; global understanding that models of energy generation like wind, solar, hydropower and biomass for electricity find it difficult to access financing [54,55].

Information collected during this review indicated that many of the briquette producers are seeking support from non-commercial sources or angel investors (not easy to find) to expand or improve their operations. The perceived lending risks hinder the producers from securing commercial financing.

3.4. Awareness amongst the consumers

From a 'fuel from waste' unconference[4] held in 2011 [56], it was clear that most consumers lack knowledge of the existence of briquettes and even if they have, do not know the difference between charcoal and briquettes. An awareness campaign program need to be carried out to sensitize the population on the benefit of using fuel briquettes in terms of fuel savings, reducing respiratory diseases and environmental conservation.

The campaign should involve demonstration exercises such as the cooking of githeri[5] using briquettes, offering of free briquette samples and the actual way of setting the briquette in the briquette stove. This can take place in public places, in media and even inculcated in the curriculum at the lower primary school level.

Finally, the setting up of "one stop shop" in major market centers for project assistance in terms of briquette making and use, machine use and maintenance and also any new efficient and effective way(s) of making and utilizing the briquettes.

[4] The term 'unconference' was used to refer to the scale of the informal meeting among the various briquette producers and other interested stakeholders.

[5] A mixture of cooked maize and beans and common traditional food in Kenya.

4. Opportunities

Immense opportunities remain untapped in the briquette industry in Kenya. The opportunities are available for all scales of businesses to grow. The scale of businesses include: the biomass feedstock suppliers, the briquette machine fabricators, the briquette producers and even the end-use consumers. From the data (Table 2), one observes the huge opportunities that are in briquette making in Kenya. The data was generated from eighteen briquette producers as a result of the administration of questions with fixed and open answer alternatives on the part of the author while engaging with the briquette producers. This was to review briquette production in terms of briquette shape, raw material used and their mixing ratio, briquette equipment used, dimension of briquette made, rate of production, selling price and the manpower required. A quantitative method was employed due to the nature of data required [57].

There being no official or unofficial list of briquette producers, the producers were to be identified. From a report on previous briquetting activity [18], the author found the location and the people involved. Five briquette producers were found and their personal contacts established. The five briquette producers had personal contacts of twenty more briquette producers. Out of the twenty producers, two were found to be established companies in briquette making.

A telephone call made to all the twenty-five briquette producers found eighteen producers who were willing to participate in the question and answer exercise. Five producers could not be reached at all while one company in Hardy area, Nairobi declined to participate and another in Hurlingham area, Nairobi reported to have temporarily stalled.

The following observations were made:

1) Application of briquettes varies from meeting the demands of the households such as cooking and heating, to institutions such as primary schools and Catholic Church in Babadogo, Nairobi.
2) Some briquette producers documented their rate of briquette production. The producers recorded the details of briquettes sold to the end users in receipt books. The documented sales date back two years down the line. The evidence of receipting points to the need of inculcating further business skills among the briquette producers. In addition, most briquettes are sold at points of production thus cutting on transportation costs.
3) The most commonly used method(s) for briquette making is the hand-made method (about seven briquette producers); ram-piston designed by Alfastar Industries [58] and box-type method (about five producers); motorized screw method (about three producers); wooden press designed by Legacy Foundation [43] method (about two producers) and both the motorized screw & wooden press method (one briquette producer). Fig. 8 provides a pictorial view of the various briquetting methods, number of user(s) and the rate of production.

   The hand-made briquettes though much labor-intensive, taps into the ready labor of the unemployed youth of the urban dwellers thus creating job opportunities[59]. However, the number of handmade briquette producers varies widely and that no documentation was provided on the rate of production (Fig. 8 and Table 2).

   The ram-type and motorized screw press are mostly used since they can be locally fabricated from locally available materials.

   Chardust industry has been in large scale briquette making business for the last fourteen years [60]. However, Chardust industry makes use of imported briquetting equipment which requires huge capital to procure. In comparison to the locally made briquetting equipment, the local sells at about 400$ while the imported one sells at about 50,000$ [27].

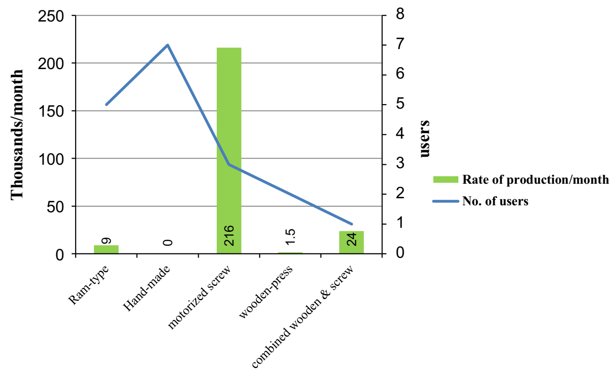


Fig. 8. The pictorial view of the various briquetting methods, number of user (s) and rate of production as detailed in Table 2.

4) Most of the briquette producers are in the age bracket of between 21 and 40 years, affirming a study [61] that this age group would likely assimilate the briquette making technology. This age bracket is outgoing and full of energy.
5) The mixing ratios are haphazard, with no specificity on appropriate mixing proportions. Most briquette producers use charcoal fines; binders used vary with some producers using waste papers while others using 2–3% of fine clay in the overall briquette mixture.
   The motorized screw presses do not require a binder apart from the water needed for the kneading process. However, the use of cassava solution as a binder to many briquette producers is proving a worthy venture. For at the time of review, a half kilogram of cassava was selling at 1$ (very cheap); briquettes burn producing no or little smoke and that it is easy to prepare the cassava solution.

5. Conclusion

It is only recently that attention has been given to introduce and promote briquette technologies in Kenya. From the data (Table 2), it can be concluded that briquette making is a self-supporting industry. Areas of intervention include availing the appropriate technology, creating a working network of engineers, researchers and the producers, ensuring ease of access to capital and imparting entrepreneurial skills to the various briquette stakeholders.

From Section 1, Tables 1 and 2 provides a context in which other alternative fuels need to be harnessed. Briquette production provides much scope for growth. Apart from addressing the challenge of waste management, briquette fuel is efficient and the burning briquette produces minimal greenhouse gas emissions especially when used in well ventilated spaces as compared to other local fuels.

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